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ABSTRACT

Described is a one-hour overview of the unit processes which comprise a municipal wastewater treatment system. Topics covered in this instructor's guide include types of pollutants encountered, treatment methods, and procedures by which wastewater treatment processes are selected. A slide-tape program is available to supplement this component of the Working for Clean Water Project. The program's goal is to provide technical information in lay language to citizen groups interested in water quality planning. (Author/WB)

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Working for Clean Water

An Information Program for Advisory Groups

Municipal Wastewater Processes

Instructor Guide

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION

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This project is dedicated to the memory of Susan A. Cole.

Municipal Wastewater Processes

A municipal wastewater treatment plant is an assembly of unit treatment processes. Each unit process is selected to treat a certain pollutant or group of pollutants. The processes must be put together in such a manner that the effluent from the treatment plant will meet the NPDES permit requirements set for it. In most cases, more than one combination will produce the required effluent. The consulting engineer should examine all of them in terms of effluent characteristics, ease of operation and management, and cost-effectiveness before recommending a particular system.

At the end of this session the participant should:

- Be able to describe the kinds of pollutants found in municipal wastewater
- Know how wastewater is transported to the treatment plant
- Recognize the major methods available for treating these pollutants
- Be aware of solid waste and air pollution problems associated with the use of particular treatment
- Understand how unit processes are assembled to treat pollutants to the degree required by NPDES permits.

Required Materials

☐Set of slides with cassette tape for the audiovisual presentation, "Municipal Wastewater Treatment"

☐Slide projector, cassette tape player, and screen

☐Set of transparencies with overhead projector or set of flip charts with easel and/or chalkboard for guided discussion

☐Copy of handbook, "Municipal Wastewater Processes," for each participant

☐Copy of Treatment Process Alternatives for each participant

☐Copy of Selection Wheel for Combining Wastewater Treatment Unit Processes (2 pages) for each participant. Both the wheel and the list of alternatives are located in the Appendix.

Important Notes

1. This instructor guide pertains to two handbooks, "Municipal Wastewater Processes: Overview" and "Municipal Wastewater Processes: Details."

2. Several instructional options exist. The instructor may:

   a. show the audiovisual presentation without substantive discussion

   b. discuss various wastewater treatment processes with their strengths and weaknesses, assisted by charts and diagrams

   c. engage in an exercise on treatment process selection.

Any combination of these options may be used, but almost all of them together are necessary for the total picture. If all the options are selected, a one-hour session will be insufficient.

3. This instructor guide is very technical, but it only reflects the nature of the subject matter. Meaningful involvement by citizens requires a familiarity with these technical details. However, some participants may be reluctant to devote enough effort and time to develop a rudimentary technical understanding. Sound advice is dependent upon basic knowledge.

4. Technical experts on treatment processes may be needed as a back-up at the instructional discussions.

5. The slide-tape presentation is also somewhat technical. The instructor may wish to show the presentation in parts that are of particular relevance for the local area. A preview of the script will indicate the structure of the slide-tape program.

6. Municipal processes mainly involve conventional treatment and disposal options. For a more comprehensive perspective, the instructor can consult the handbooks on small systems, multiple use, and innovative and alternative technologies.

7. If the process selection exercise is planned, the instructor must prepare copies of the chart on treatment process alternatives, and the selection wheel handout.

8. The selection exercise may involve the use of a transparency of the selection wheel. Coloring the process pathways for the Doeville, PA example, or another example, will enhance the instruction.

Suggested Activities

Introductory Comments	5 minutes
Audiovisual Presentation	15 minutes
Guided Discussion	15 minutes
Selection Exercise	20 minutes
Closing Remarks	5 minutes
TOTAL TIME	60 minutes

Introductory Comments (5 minutes)

1. Open with a statement such as "Sewage is purer than Ivory Soap. It's 99.9% water."

Point out that only 0.1% is a problem that must be dealt with.

2. Briefly review the objectives of this presentation.

List objectives on transparency or flip chart.

Audiovisual Presentation (15 minutes)

1. The slide-tape program is concerned with the basic material contained in the citizen handbook. The presentation does not present details, but it does introduce the participant to the unit processes used to treat wastewater.

Script is in Appendix in case of equipment malfunction.

2. Depending upon the needs of the participants, a portion rather than the entire slide-tape program may be most appropriate.

3. Advise participants to write down any questions or comments for later discussion. Briefly point out aspects of the slide-tape program that relate to the local situation.

Guided Discussion (15 minutes)

1. Receive questions raised by the audiovisual presentation. Answer them, or wait until appropriate places in the guided discussion.

2. Discuss the kinds of pollutants found in wastewater. Define any terms the participants do not understand.

3. Comment on the general methods used to remove the various kinds of pollutants. Define what is meant by physical, chemical, and biological methods. Give examples.

Use chart 1 on Wastewater Treatment Mechanisms.

4. Distinguish between combined and separate sewer systems. Point out the advantages and disadvantages of each type of system as related to the design of wastewater treatment facilities.

Use chart 2 on the Efficiency of Treatment Process.

5. State what is meant by primary, secondary, and advanced levels of treatment. Note the percentage removal of various kinds of pollutants in each level of treatment.

6. Discuss how unit processes are assembled to treat wastewater so that they meet the required effluent standards.

Use chart 3 on Removal Efficiencies and Cost for a Wastewater treatment Sequence.

Pages 76-78 in Environmental Pollution Control Alternatives: Municipal Wastewater provide additional information for use with this chart.

Go through each unit process separately, highlighting the percent of removal for:

BOD (Biochemical Oxygen Demand)
COD (Chemical Oxygen Demand)
Suspended Solids
Nitrogen
Phosphorus

Compare the cost of each additional unit process with the amount of pollutants removed. Point out that the initial 85 percent of the pollutants are easy to remove and a lot less costly than the last 15 percent.

Mention the proportion that sludge handling contributes to the total cost.

- 50 percent of the cost for secondary treatment is for organic sludge handling (see first bar on the graph).

- 50 percent of the cost of phosphorus removal is for handling the chemical sludge (see second bar on the graph).

Optional Exercise

Use handouts on Treatment Process Alternatives and Selection Wheel for Combining Unit Processes for Wastewater Treatment Systems (2 pages).

Selection Exercise (20 minutes)

Note: the following illustrative example is provided to give the participant an idea of how unit processes are combined and the many alternative combinations that exist.

Additional information can be found in A Guide to the Selection of Cost-Effective Wastewater Treatment Systems by Robert H. Van Note et al. Consult Selected Resources for reference details.

Illustrative Example

The Problem

The community of Doeville, PA is required to construct a wastewater treatment plant having a capacity of 20 million gallons per day (MGD). The effluent will discharge into a river 20 miles upstream from a combination flood control-recreation area reservoir. Because of the reservoir the NPDES permit requirements for the effluent quality are:

(List on chalkboard or flip chart)

BOD	5 mg/L
Suspended Solids	3 mg/L
Total Phosphorus	1 mg/L
Total Nitrogen	30 mg/L

The Solution

Unit processes can be combined in a variety of sequences to make up viable wastewater treatment for Doeville. Varying degrees of effluent quality can be achieved, depending upon the choice of combinations.

The Selection Wheel

The selection wheel is used to combine unit processes together in a logical manner. A variety of sequences are given that have proven effective in achieving the eighteen different effluent quality standards shown on the wheel.

The circles on the selection wheel represent unit processes. The letters and numbers in the circle are codes corresponding to specific unit processes. A list of the process names along with their letter/number codes can be found on the handout entitled "Wastewater Treatment Unit Processes."

Unit processes in the wheel diagram are connected by lined pathways to form various wastewater treatment systems. In general, by beginning at the innermost unit processes and proceeding radially outward along the pathway lines, progressively higher levels of treatment are obtained. The pathways need not be followed to the end, but can be terminated at various intermediate stages depending upon the degree of treatment desired.

The pathways as shown on the wheel do not include disinfection, preliminary treatment, and raw wastewater pumping. They are either common to all or none of the treatment alternatives producing a given effluent, and therefore exert no influence on the choice of one system over another. However, they must be included in the determination of the costs associated with each treatment system.

Using the Selection Wheel

Step 1 Find the circle which corresponds with the desired effluent quality.

Step 2 Follow around the selected circle and note each unit process located on the line. These are the final unit processes in treatment systems producing the desired effluent quality.

Step 3 Beginning with each of these final processes individually, follow the lined pathways toward the center of diagram. Note each unit process located on the pathway until the innermost unit process (A series) is reached. This process is the initial one in the treatment sequence.

Some pathways may branch. Therefore, more than one system can result from a single beginning process. Make note of all possible combinations that will give the required effluent.

It should be emphasized that these diagrams are general in nature and cannot completely reflect local conditions. The given effluent values are really average values. To determine the exact effluent quality that can be achieved by specific processes or systems at the local level, more information is necessary. Individual analyses for each project must be made by the engineering consultant.

The unit processes selected here are for wastewater treatment only. Sludge handling systems will also have to be selected. Then a cost comparison of alternative systems must be done before a choice is made.

Also note that this selection process does not include innovative and alternative technologies or multiple use options. Therefore, this selection method, at best, gives an initial array of conventional processes. Innovative and alternative technologies and other considerations must also be taken into account before processes are selected.

Doeville's Alternatives

The effluent which meets Doeville's NPDES permit requirements is located on the sixth circle from the center of the selection wheel. It shows an effluent having a BOD of 5 mg/L, suspended solids of 3 mg/L, and phosphorus of < 1 mg/L. The diagram shows that eleven different process combinations will provide the required effluent quality for a 20 MGD wastewater treatment plant. These eleven processes are listed on the next page:

(List combinations on chalkboard or flip chart)

1	2	3	4	5	6	7	8	9	10	11
E	E	E	E	E	E	E	E	E	E	E
D	D	D	D	D	D	D	D	D	D	D
A-2	B-2	B-3	B-3	C-2	C-3	C-3	C-4	C-5	F-1	F-2
	A-3	A-4	A-5	A-3	A-4	A-5	A-1	A-1	B-1	C-1
									A-1	A-1

Note: Preliminary treatment (AA) and disinfection (R) are needed in all the above process combinations.

Using combination number 2 and the list of wastewater treatment unit processes with their designated codes, the treatment sequence is as follows:

AA Preliminary Treatment
A-3 Single Stage Lime Addition
B-2 Trickling Filter
D Filtration
E Activated Carbon
R Disinfection

If there is sufficient time, the various unit processes can be discussed in more detail. Flow charts of the unit processes selected in the Doeville example are provided in the Appendix. The changes in wastewater quality after treatment by each additional unit process are noted on the flow charts.

The effluent quality after treatment by the unit processes selected in combination number 2 would have a BOD of 4 mg/L, suspended solids of 2 mg/L, and phosphorus of 0.8 mg/L. This quality easily meets Doeville's NPDES permit requirements.

Closing Questions and Answers (5 minutes)

1. Address any concerns the advisory group may have on the selection of treatment processes.

2. Summarize the session topics. The section entitled "Main Points" at the end of the handbook, *Municipal Wastewater Processes: Overview*, may be used for the summary.

Use flip chart or chalkboard.

Selected Resources

Environmental Pollution Control Alternatives: Municipal Wastewater. Publication Number EPA-625/5-76-012. Washington, DC: U.S. Environmental Protection Agency, May 1976. 79 pp. Order No. 5012.

This document is an excellent non-technical discussion of available municipal wastewater treatment processes. It describes the processes, gives costs and energy requirements, and discusses its efficiency, advantages and disadvantages. It is available from CERI, Technology Transfer, U.S. Environmental Protection Agency, Cincinnati, OH 45268. Give the document title and order number when placing an order.

Innovative and Alternative Technology Assessment Manual. MCD-53. Washington, DC: U.S. Environmental Protection Agency, September, 1978. 388 pp.

This document contains fact sheets for 117 different wastewater treatment process variations. Each fact sheet describes the process and its modifications and discusses technology status, applications, limitations, equipment manufacturers (list only), environmental impact, and references. Flow diagrams, capital, and operating costs are also given. It is available as MCD-53 from General Services Administration, Centralized Mailing Services, Building 41, Denver Federal Center, Denver, CO 80225.

Metcalf and Eddy, Inc., Wastewater Engineering: Treatment, Disposal, Reuse. 2nd Edition. Revised by G. Tchobanoglous. New York: McGraw-Hill Book Co., 1979.

This document is a detailed, very technical book covering the design and function of wastewater treatment processes. Its 16 chapters with 8 appendices are excellent reference materials, but are unsuitable for lay persons.

Van Note, Robert H. et al. A Guide to the Selection of Cost-Effective Wastewater Treatment Systems. Publication Number EPA-430/9-75-002. Washington, DC: Office of Water Programs Operations, U.S. Environmental Protection Agency, July, 1975. 229 pp.

This document presents information which can be used to determine the alternate municipal wastewater treatment process schemes that will meet specific effluent guidelines. Procedures and information which can be used in determining the cost of each alternate scheme are also given. It is available from the National Technical Information Service, 5285 Post Royal Road, Springfield, VA 22161. The cost is $28 a copy; a 15 percent discount is given for orders of 20 or more copies.

Appendix

A. Charts for use by the instructor in the suggested activities. The charts may be used to make transparencies, or the contents may be copied onto flip charts.

1. Wastewater Treatment Mechanisms

2. Efficiency of Treatment Processes

3. Removal Efficiencies and Cost for a Wastewater Treatment Sequence.

B. Handouts for use by the instructor in the selection exercise. Copies will need to be made for each participant.

1. Selection Wheel for Combining Unit Processes for Wastewater Treatment Systems (two pages)

2. Treatment Process Alternatives

C. Flow Charts for use by the instructor in the selection exercise.

1. Preliminary Treatment

2. Single Stage Lime Addition

3. Trickling Filter

4. Filtration

5. Activated Carbon

6. Disinfection

D. Copy of the script for the slide-tape program, "Municipal Wastewater Treatment."

Wastewater Treatment Mechanisms

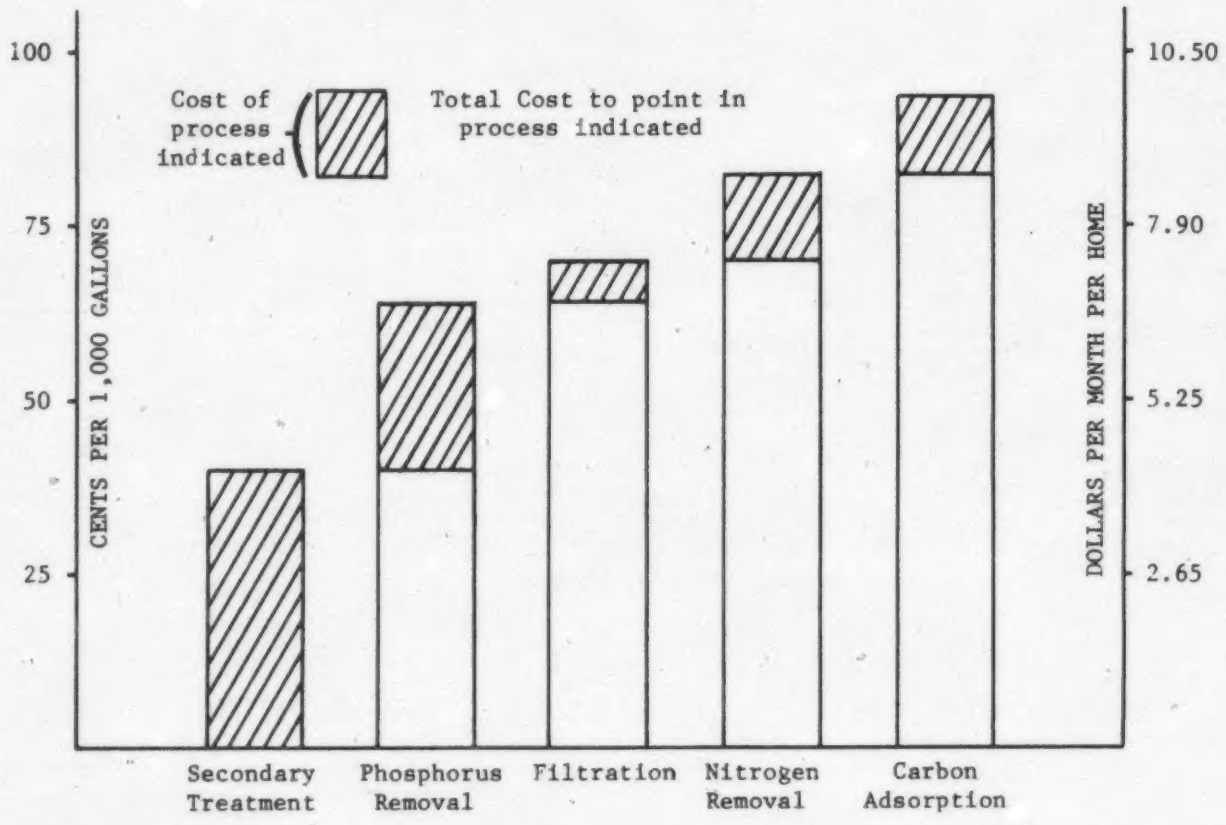
Type	Function	
Physical	Settle	Flotation
	Filter	Selective transport
	Adsorption	
Chemical	Precipitation	
	Oxidation	
Biological	Metabolism	

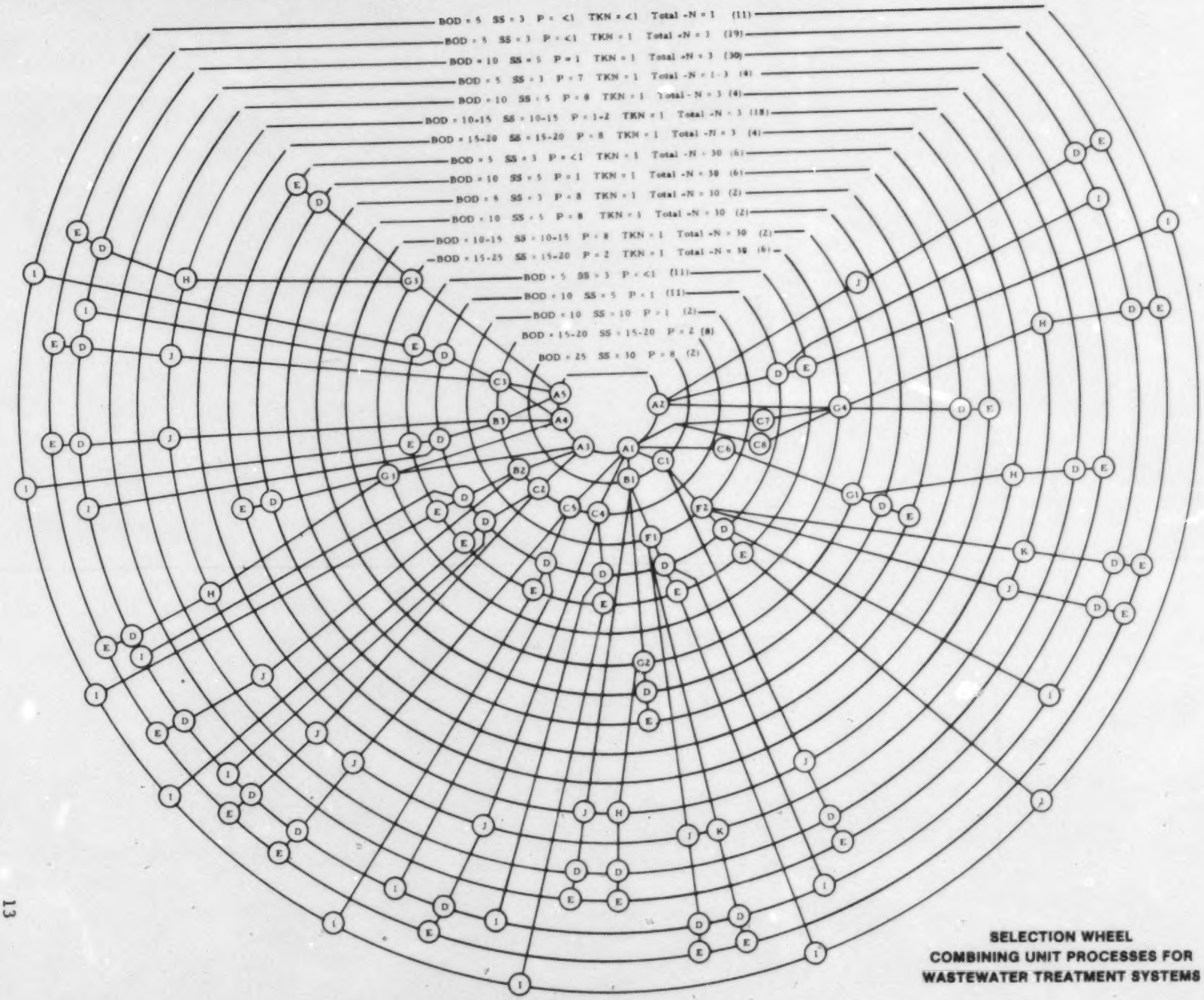
Pollutant Removal Percentages

Pollutant	Primary Treatment	Secondary Treatment	Advanced Treatment
BOD	25-30	80-95	90-99
Suspended solids	60-65	80-95	90-95
Nutrients	Minimal	Minimal	90-95

Removal Efficiencies and Cost for a Wastewater Treatment Sequence

Pollutant	Secondary Treatment	+ Phosphorus Removal	+ Filtration	+ Nitrogen Removal	+ Carbon Absorption
	Percent Removal				
BOD	90	97.5	99	99	99.5
COD	80	90	91	91	97.5
Suspended Solids	90	97.5	100	100	100
Nitrogen	10	10	10	90	92.5
Phosphorus	10	80	99	99	99




BOD = 5 SS = 3 P = <1 TKN = <1 Total -N = 1 (11)
BOD = 5 SS = 3 P = <1 TKN = 1 Total -N = 3 (19)
BOD = 10 SS = 5 P = 1 TKN = 1 Total -N = 3 (30)
BOD = 5 SS = 3 P = 7 TKN = 1 Total -N = 1-3 (4)
BOD = 10 SS = 5 P = 8 TKN = 1 Total - N = 3 (4)
BOD = 10-15 SS = 10-15 P = 1-2 TKN = 1 Total -N = 3 (18)
BOD = 15-20 SS = 15-20 P = 8 TKN = 1 Total -N = 3 (4)
BOD = 5 SS = 3 P = <1 TKN = 1 Total -N = 30 (6)
BOD = 10 SS = 5 P = 1 TKN = 1 Total -N = 30 (6)
BOD = 5 SS = 3 P = 8 TKN = 1 Total -N = 30 (2)
BOD = 10 SS = 5 P = 8 TKN = 1 Total -N = 30 (2)
BOD = 10-15 SS = 10-15 P = 8 TKN = 1 Total -N = 30 (2)
BOD = 15-25 SS = 15-20 P = 2 TKN = 1 Total -N = 30 (6)
BOD = 5 SS = 3 P = <1 (11)
BOD = 10 SS = 5 P = 1 (11)
BOD = 10 SS = 10 P = 1 (2)
BOD = 15-20 SS = 15-20 P = 2 (8)
BOD = 25 SS = 30 P = 8 (2)

SELECTION WHEEL
COMBINING UNIT PROCESSES FOR
WASTEWATER TREATMENT SYSTEMS

WASTEWATER TREATMENT UNIT PROCESSES

AA. Preliminary Treatment
Influent: Raw wastewater

AB. Raw Wastewater Pumping
Influent: Effluent from AA

A. Primary Sedimentation
Influent: Effluent from AA or AB
- A-1 Conventional
- A-2 Two-Stage Lime Addition
- A-3 Single Stage Lime Addition
- A-4 Alum Addition
- A-5 $FeCl_3$ Addition

B. Trickling Filter
- B-1 Influent: Effluent from A-1
- B-2 Influent: Effluent from A-3
- B-3 Influent: Effluent from A-4 or A-5

C. Activated Sludge
- C-1 Conventional
  Influent: Effluent from A-1
- C-2 Conventional
  Influent: Effluent from A-3
- C-3 Conventional
  Influent: Effluent from A-4 or A-5
- C-4 Alum Addition
  Influent: Effluent from A-1
- C-5 $FeCl_3$ Addition
  Influent: Effluent from A-1
- C-6 High Rate
  Influent: Effluent from A-1
- C-7 High Rate & Alum Addition
  Influent: Effluent from A-1
- C-8 High Rate & $FeCl_3$ Addition
  Influent: Effluent from A-1

D. Filtration
Influent: Effluent from A-2, B-2, B-3, C-2, C-3, C-4, C-5, F-1 or F-2 G-1, G-2, G-3, G-4, H, J, K

E. Activated Carbon
Influent: Effluent from D

F. Two-Stage Tertiary Lime Treatment
- F-1 Influent: Effluent from B-1
- F-2 Influent: Effluent from C-1

G. Biological Nitrification
- G-1 Influent: Effluent from C-6
- G-2 Influent: Effluent from B-1
- G-3 Influent: Effluent from A-3, A-4 or A-5
- G-4 Influent: Effluent from A-2, C-7 or C-8

H. Biological Denitrification
Influent: Effluent from G-1, G-2, G-3 or G-4

I. Ion Exchanges
Associated with A-2, B-2, B-3, C-2, C-3, C-4, C-5, F-1, or F-2

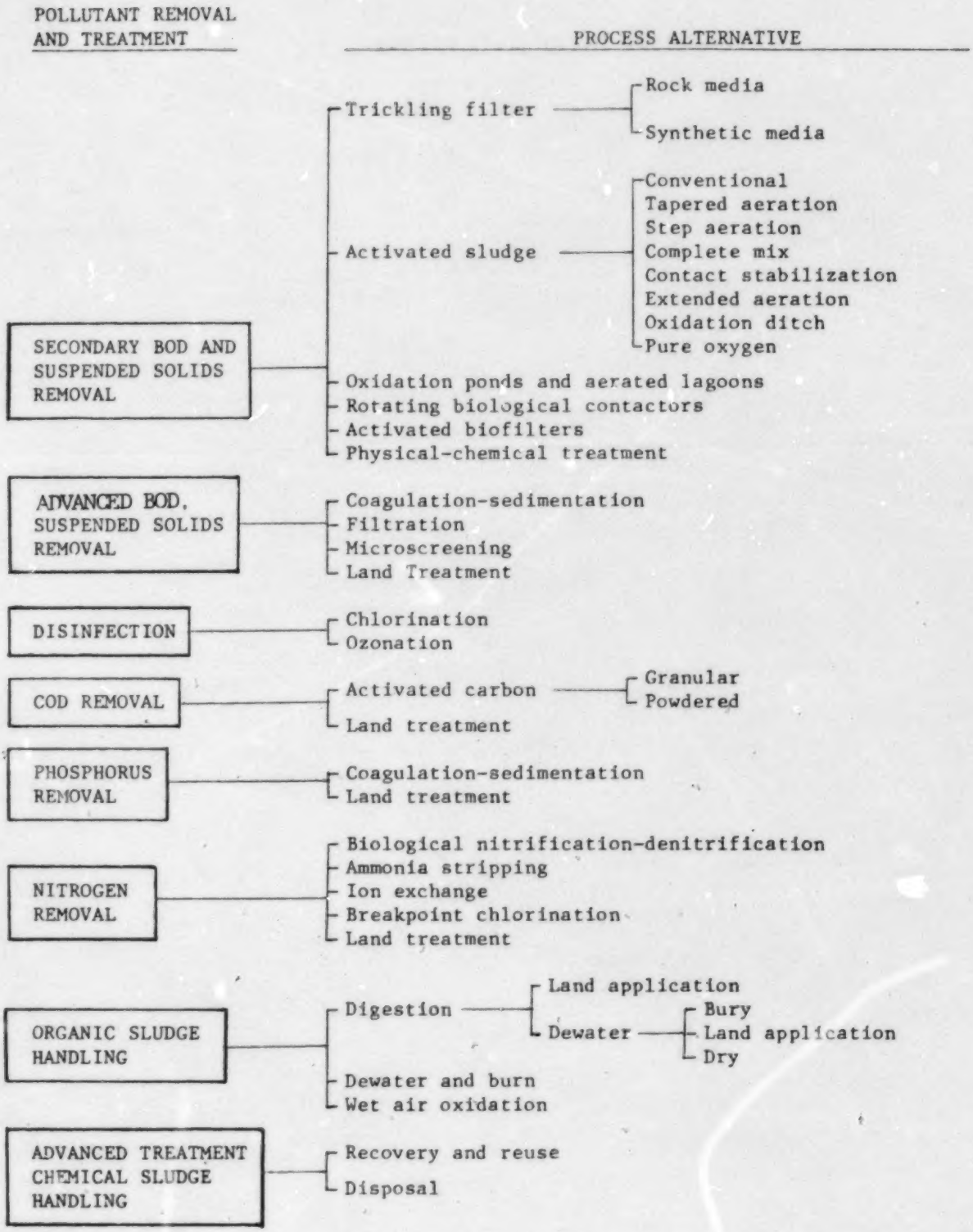
J. Breakpoint Chlorination
Influent: Effluent from A-2, B-1, B-2, B-3, C-1, C-2, C-3, C-4, C-5, F-1 or F-2

K. Ammonia Stripping
Influent: Effluent from F-1 or F-2

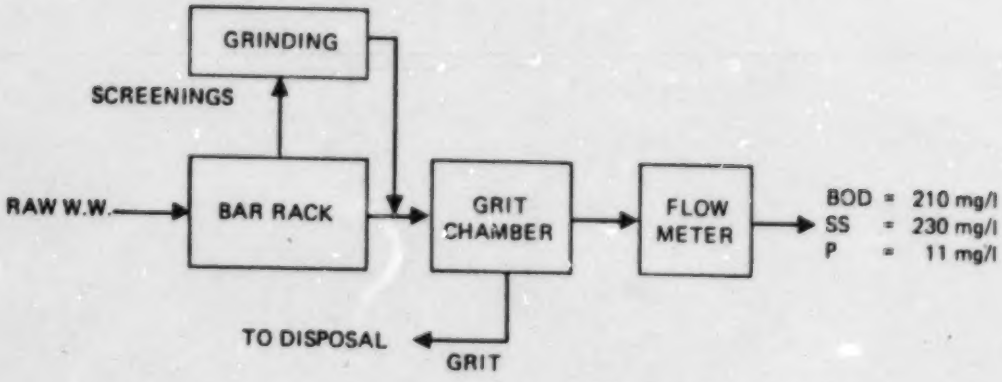
R. Disinfection
Influent: Effluent from any treatment process

From A Guide to the Selection of Cost-Effective Wastewater Treatment Systems by Robert H. VanNote et al. Publication Number EPA-430/9-75-002. Washington, DC: Office of Water Programs, U.S. Environmental Protection Agency, July 1975.

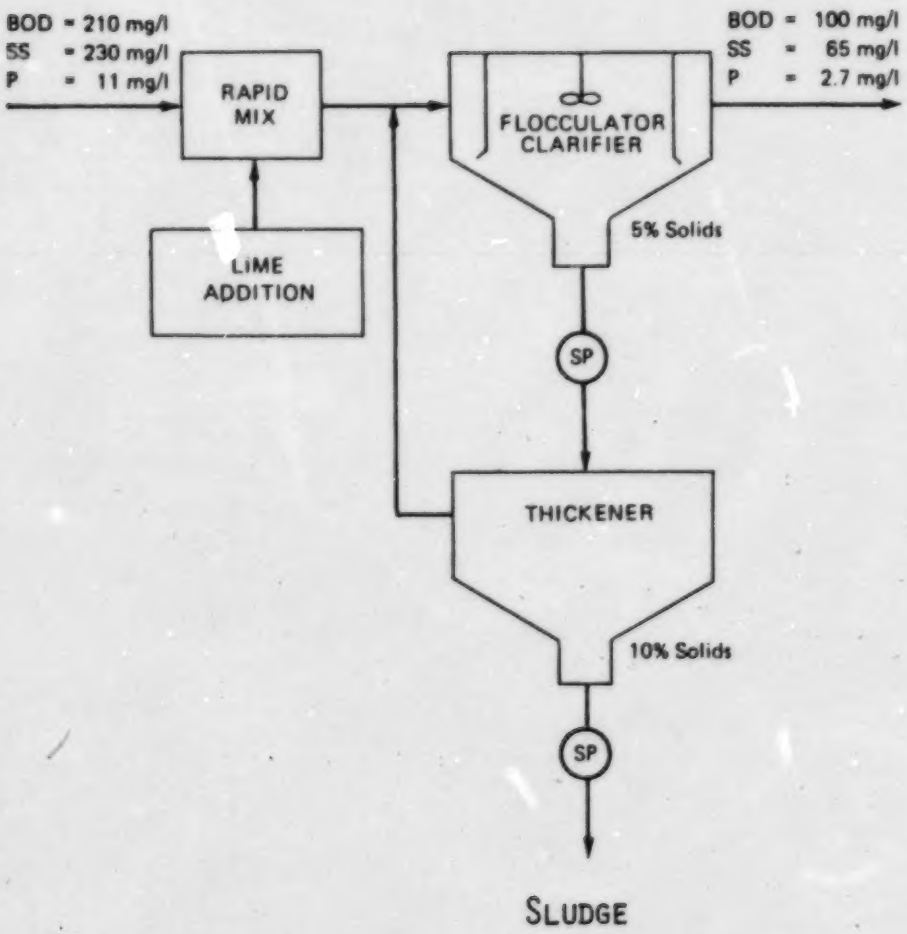
TREATMENT PROCESS ALTERNATIVES



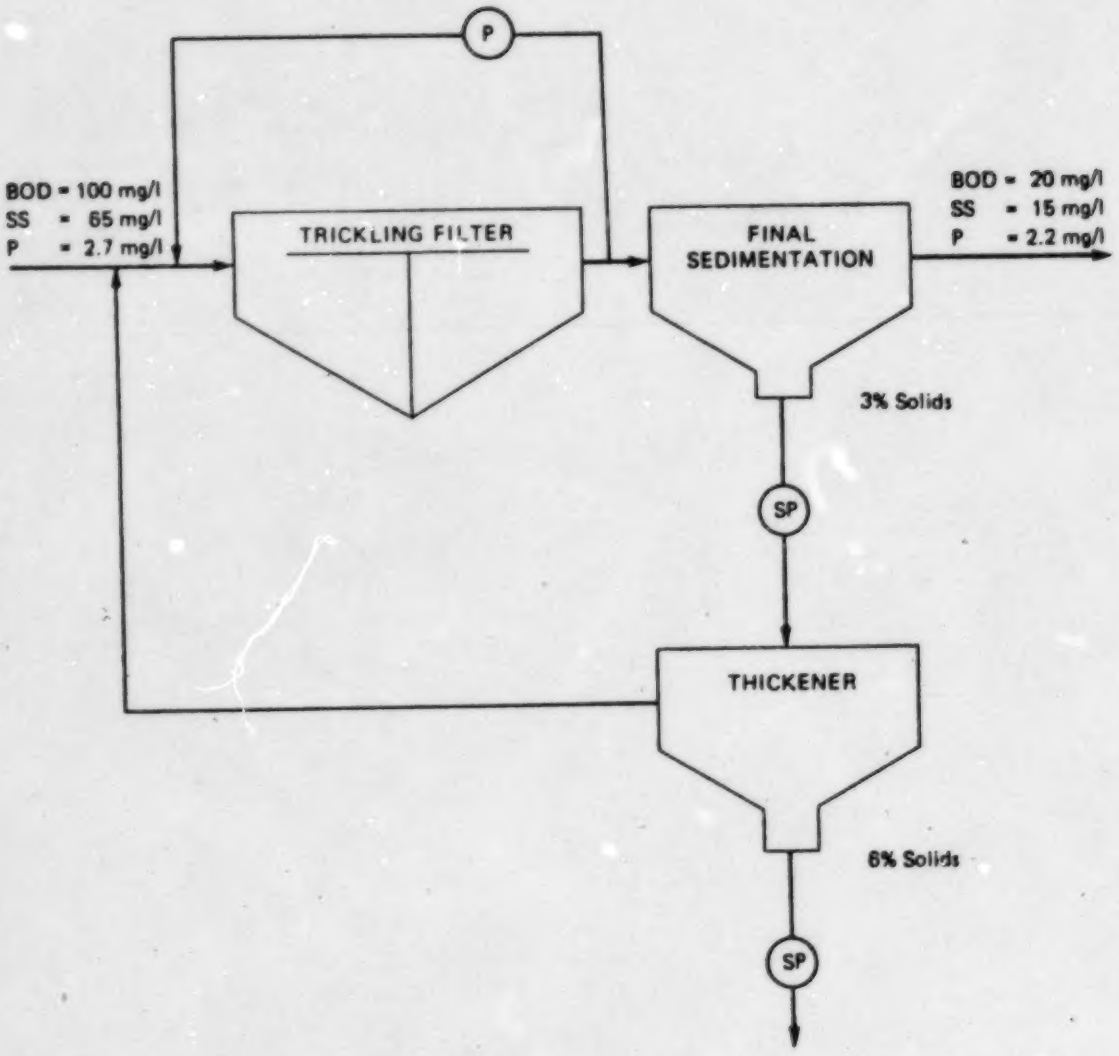
AA. PRELIMINARY TREATMENT
Influent: Raw Wastewater



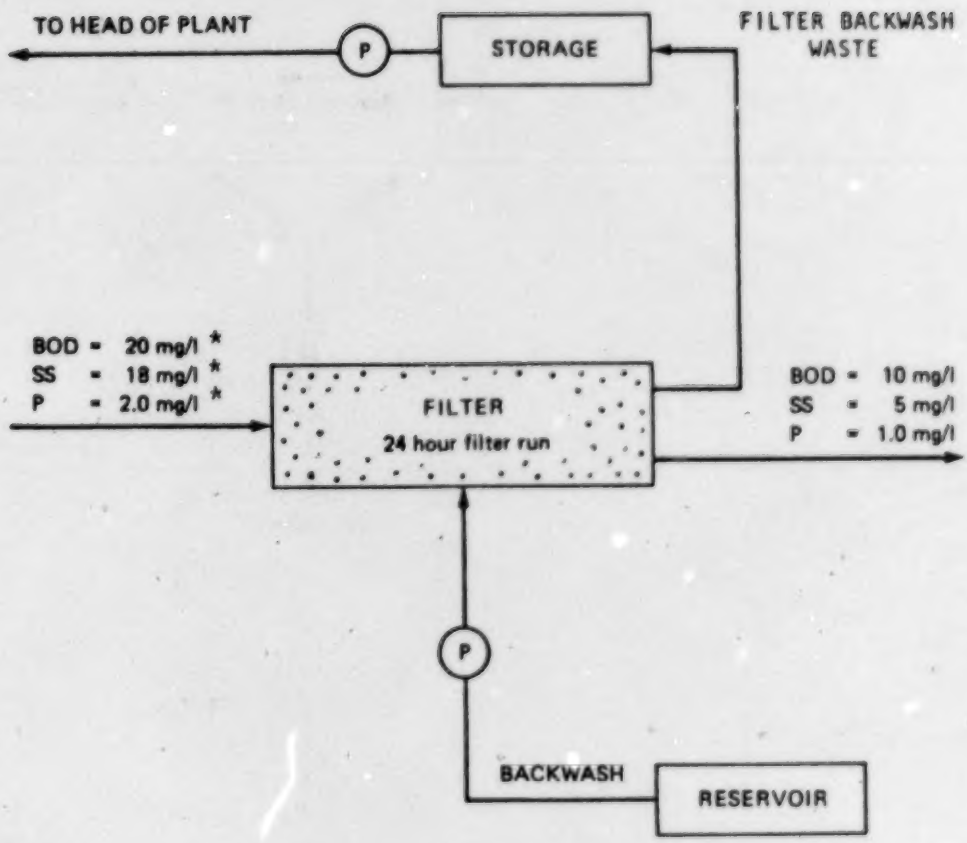
A-3. PRIMARY SEDIMENTATION – SINGLE-STAGE LIME ADDITION
Influent: Effluent from Preliminary Treatment AA



B-2. TRICKLING FILTER
Influent: Effluent From Primary Sedimentation – Single-Stage Lime Addition A-3



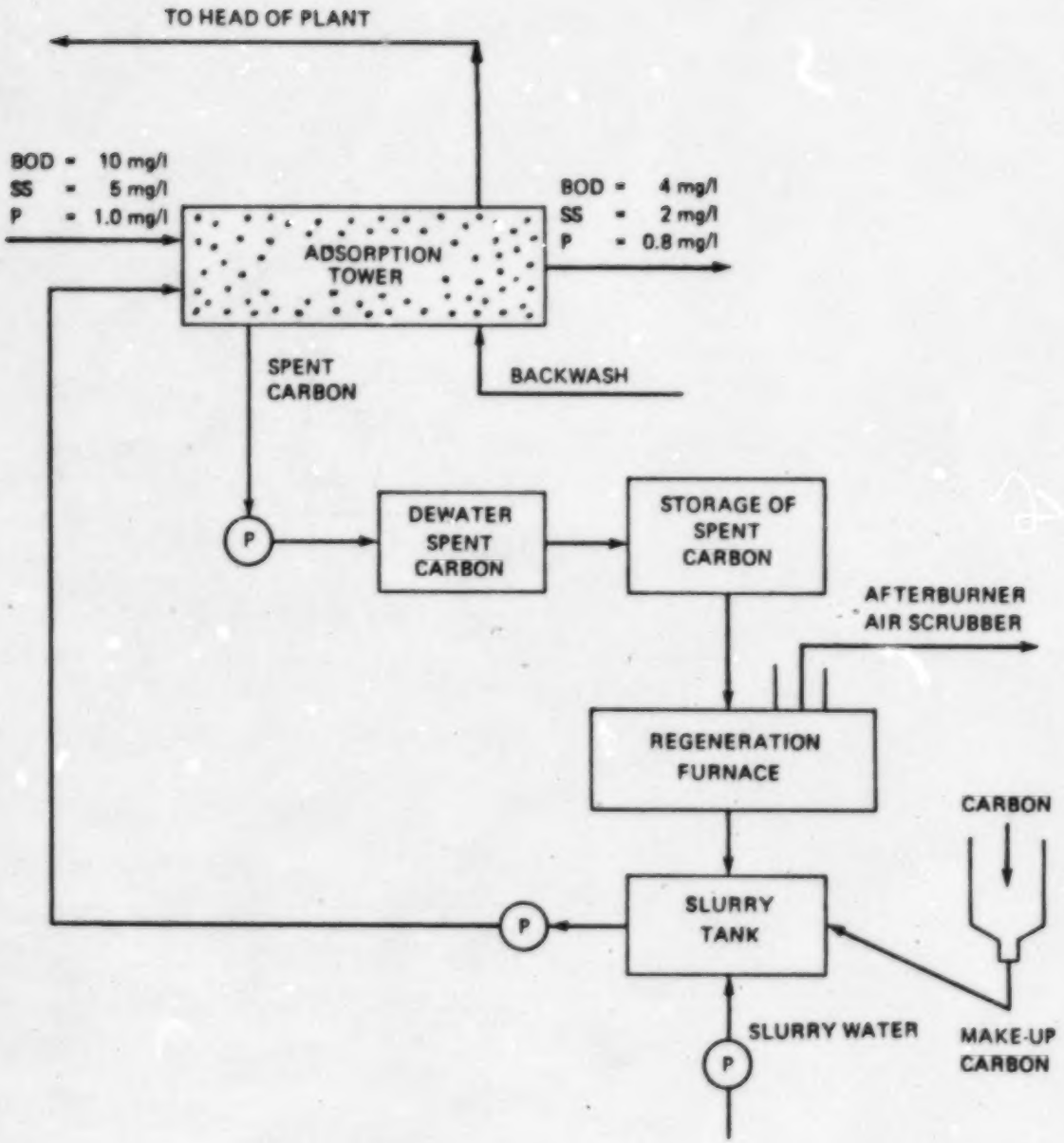
D. FILTRATION
Influent: Effluent from Trickling Filter B-2, B-3



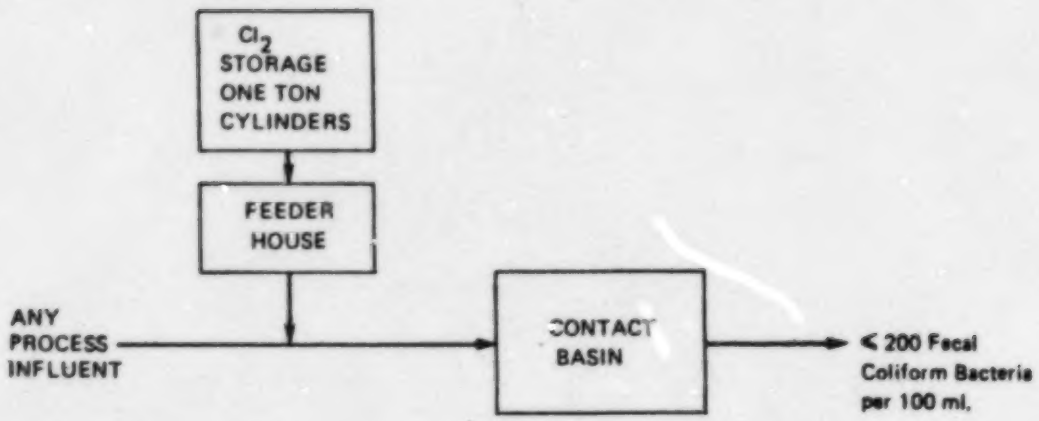
*Averaged values from above influent.

E. ACTIVATED CARBON

Influent: Effluent from Filtration D



R. DISINFECTION
Influent: Any Process Effluent



Audiovisual Script

MUNICIPAL WASTEWATER TREATMENT

Slide Description	Narrative
1. TITLE	MUSIC
2. Picture: Sewers	Most homes and businesses and many industries dispose of their wastes through a public sewer system. Simply put, sewer systems ultimately carry the diluted waste to our streams and rivers.
3. Picture: Discharge into stream from treatment plant	However, this mixture and waste material cannot be discharged directly.
4. Picture: Bar of Ivory soap	In reality sewage is more than 99.9% pure water. That's purer than ivory soap. The pollution is contained in the remaining one tenth of one percent of waste.
5. Graphic: Sewage contents	Sewage may contain disease causing bacteria and viruses, toxic substances, and organic materials which adversely effect the natural quality of streams and lakes. Of course, many harmless substances are also carried in sewage.
6. Graphic: Physical, chemical, biological; with symbolic drawings of each	There are many physical, chemical, and biological methods developed for removing the various waste materials from sewage.
7. Graphic: Picture of solids entering tank and settling	Most of these methods convert non-settleable particles into something that can be settled, and then removed from the water.
8. Graphic: Schematic of Primary — secondary — advanced	It is useful to divide the treatment methods used into three stages, primary, secondary, and advanced.
9. Graphic: #8 (highlight primary)	The first stage of treatment is referred to as the Primary Stage. In this stage, larger solid materials are removed by mechanical means such as a screen or through settling.

10.	Graphic:	#8, highlight	In the Secondary Stage, smaller materials usually are removed through a process in which the wastewater is treated biologically to remove the organic matter. The process has some of the same functions as a stream or lake.
11.	Graphic:	#8, highlight Advanced Treatment	Another stage is referred to as Advanced Treatment. Processes used in this treatment stage remove specific pollutants which remain in the water after Primary and Secondary Treatment. While primary and secondary treatment are nearly always required for municipal wastewater, advanced treatment is not. It is used only when the quality of normal secondary effluent is not good enough.
12.	Picture:	Wastewater treatment plant	Let's look at a typical municipal waste water treatment plant and identify some common methods of waste removal. The plant is the Swatara Treatment Plant serving Swatara Township in Central Pennsylvania. It includes primary and secondary treatment stages as well as sludge treatment processes.
13.	Picture:	Sewage flow	Sewage arrives at the treatment plant through a network of drains and pipes beneath the community's streets. Usually the sewage flows by gravity.
14.	Graphic:	Pump station	However, in certain areas the wastewater must be pumped.
15.	Picture:	Bar rack	When the sewage enters the treatment plant it passes through a metal screen called a bar rack. The large solid materials such as rags and leaves are trapped by this bar rack and removed by the treatment plant operators.
16.	Picture:	Comminutor	The large materials are ground into smaller sizes by a machine called a comminutor. The comminutor does not remove any solid matter but prepares it so that it can be removed more efficiently in subsequent treatment processes.
17.	Picture:	Clarifier (settling tanks)	The wastewater then enters a large settling tank. Slow movement in this tank allows heavier particles to sink to the bottom where they can be removed easily.

18.	Picture:	Overflow from clarifier	After this primary settling stage, the water still contains many small particles which cannot be settled. However, these small particles, referred to as organics, can be removed in secondary treatment.
19.	Picture:	Activated sludge tanks	The secondary treatment method used at Swatara is called the activated sludge process. The water in this process contains many microscopic organisms which feed on organic particles.
20.	Picture:	Close up - activated sludge	The water is aerated to provide oxygen and mixing for the organisms.
21.	Picture:	Clarifier	The organisms, particles, and water, together called activated sludge, flow into a second clarifier or settling tank. In this clarifier the water movement slows and allows the activated sludge to settle to the bottom.
22.	Graphic:	Recycle flow diagram	The organisms which consume the organic food are then pumped back into the aeration tank to work on the new waste entering the activated sludge process. The excess sludge is delivered to the sludge handling processes which will be described later.
23.	Picture:	Chlorine contact tanks	After flowing through various processes at the Swatara plant, the treated water, called effluent, travels to an area where chlorine is added to kill all disease causing bacteria.
24.	Picture:	Chlorine feeder	Chlorine may be purchased in cylinders as a gas and dissolved in water in a device called a chlorinator.
25.	Picture:	Sewage raw, primary, secondary effluent	The water is still not pure but has been cleaned to a level such that it is not harmful to the stream into which it flows. In this illustration, the raw wastewater is on the left, the primary effluent in the center and the secondary effluent on the right.
26.	Graphic:	Flow diagram of WWTP	Let's now examine what is done with the material which was removed from the

			various stages of the Swatara treatment plant. We have separated the sludge processes from the wastewater treatment stages. However, wastewater treatment cannot function without adequate sludge handling processes. They must go hand in hand!
27.	Picture:	Sludge poured from beaker	The particles removed in primary and secondary treatment have formed a dark, thick material which we call sludge. This sludge must first be concentrated so that it can be disposed of safely and economically.
28.	Picture:	Gravity thickening	At Swatara the first step in our treatment of sludge is called gravity thickening.
29.	Graphic:	Gravity thickening	The gravity thickening process is essentially a settling process with the water remaining on top being pumped back to the beginning of the plant.
30.	Picture:	Holding tank	Sludge then travels to an aerobic holding tank where air is injected to prevent the sludge from becoming odorous.
31.	Picture:	Centrifuge	Additional water is removed from the sludge in a centrifuge. The centrifuge spins rapidly forcing the sludge to separate from the liquid.
32.	Graphic:	Centrifuge	The solids are spun to the outside of the bowl and later scrapped away. Liquid is again returned to the beginning of the plant for treatment.
33.	Graphic:	Incinerator	The final step in sludge processing at Swatara is incineration in which the remaining moisture is evaporated and the organic matter burned and reduced to ash.
34.	Graphic:	Flow diagram "Primary, Secondary, Advanced"	The Swatara does not use Advanced Treatment methods because at this time they are not needed. It has no problem with either toxic materials or plant nutrients that have to be removed from the effluent. Secondary treated effluent is adequate.
			MUSICAL BRIDGE
35.	Word slide:	Waste treatment alternatives	Let's now look at some alternatives for each of the wastewater treatment stages

			and the sludge treatment stage used at the Swatara plant. Recall that this plant used a bar rack, grinder and sedimentation to remove large solid materials in the Primary Stage.
36.	Picture:	Grit chamber	Another pretreatment option used in the Primary Stage is called grit removal. By installing a grit chamber, very heavy solids, such as sand, which may ruin pumps are removed. Air is added to create a rotating motion which causes the heavier grit to be thrown to the bottom of the tank while the smaller, lighter organic solids move on.
37.	Picture:	Grease incinerator	In this tank the air also causes grease to float. It is skimmed off the top and burned in an incinerator.
38.	Graphic:	Wedge wire screen	Primary treatment might also be accomplished by screening alone, for example a wedge wire screen. In this device separation of solids is accomplished as the water falls through the screen while the solids slide to the bottom, where they are removed. In fact, there is a school of thinking among design engineers that settling at the primary stage is not needed at all.
39.	Picture:	Secondary Treatment alternatives 4 picture composite	For Secondary Treatment, numerous variations of the biological treatment process are available.
40.	Picture:	Trickling Filter	One alternative, other than the activated sludge process used at Swatara, is the trickling filter. It consists of a bed of hard, durable material such as plastic or rock over which wastewater is sprayed.
41.	Picture:	Trickling filter rock	The plastic or rock is covered with a growth of micro-organisms which removes the organic matter as the wastewater passes down or trickles through the bed. Micro-organisms feed on organic matter just as they would in an aeration tank.
42.	Picture:	Biodiscs	Another variation of biological treatment, also using a slime that is attached to a surface, is the biological contactor or biodisc. In this process, large discs rotate slowly in a tank. Organisms attached to the discs are alternately exposed to the flowing wastewater for food, and to the air for oxygen. The organics in the wastewater are removed by the micro-organisms.

43.	Picture: Lagoon	Oxidation ponds are one of the most common biological treatment alternatives used in secondary wastewater treatment. Wastewater flows into a pond or lagoon where the organic materials are consumed by bacteria in the water.
44.	Picture: Split screen slide of 4 alternatives	Oxygen is supplied by diffusion from the atmosphere, by plant life such as algae; by air pipes along the bottom or by large mixers on the surface. The settled sludge is removed by dredging.
45.	Picture: Oxidation ditch	The oxidation ditch is an alternative which is a combination of the lagoon and activated sludge processes. It requires a final clarifier, however, in contrast to a lagoon, which does not.
46.	Picture: Land treatment	Land treatment of wastewater may be used either as a secondary or advanced treatment method. Here the wastewater is applied to the soil. Microorganisms always present in the soil, consume the organic matter. Much of the nitrogen and phosphorus in the wastewater are used by plants as nutrients or absorbed on soil particles. The treated water evaporates, runs off into streams, or filters into the ground. When used as secondary treatment, land treatment follows only primary treatment. When land treatment follows secondary treatment, it is considered an advanced treatment process.
47.	Graphic: Advanced treatment	Let us now consider some other types of advanced treatment which may be used if high removals of various materials present in wastewater are required.
48.	Picture: Microscreens	For some receiving waters, secondary treatment may not remove enough suspended solids. Additional removal of suspended solids may be enhanced by filtration of the wastewater through small rotating screens called microscreens or a granular filter bed. This

filtration usually follows sedimentation. The microscreen is a rotating cylinder of fine wire cloth which is cleaned continuously as it rotates.

49. Graphic: Filter bed cross section

The granular filter bed is composed of increasingly smaller sizes of either sand and coal which trap the organic materials as the water flows down through the filter. After the filter becomes clogged, the flow is reversed and the removed particles are flushed back into the plant for further treatment.

50. Picture: Eutrophicated lake

One potentially harmful element in wastewater is phosphorus, a necessary plant nutrient. Phosphorus is good for your garden and your lawn, but in excess amounts is a nuisance in surface waters.

51. Graphic: Precipitation flows scheme

Phosphorus can be removed in the treatment plant by chemical precipitation. The precipitating chemicals combine with the phosphorus and other solids in the wastewater, causing them to clump together and settle to the bottom.

52. Picture: Clear clarifier

An added benefit of this precipitation is a remarkably clear effluent which often makes it possible to see the sludge collection scrapers at the bottom of the final clarifier as you can at this treatment plant.

53. Picture: Activated sludge tank

In another approach, the activated sludge process can be modified so that the microorganisms themselves precipitate the excess phosphorus. The phosphorus is then either removed with the excess activated sludge or released and separated from the sludge before it is returned to the aeration tank. The separated phosphorus can be reclaimed as a fertilizer component. This is a recently developed process which would qualify as innovative or alternative.

54.	Words: Nitrogen, carbon, phosphorus with Nitrogen highlighted	Nitrogen is another essential plant nutrient that sometimes must be removed from wastewater, or at least chemically altered in the wastewater. Nitrogen initially is present in wastewater as ammonia, which in streams may be toxic to organisms. One common way of dealing with ammonia is to convert it into a nontoxic substance.
55.	Graphic: Nitrification, denitrification reactions	This conversion can be done by a process called biological nitrification in which special bacteria convert ammonia into more desirable nutrients. An additional step, denitrification, may sometimes be added. This process continues the bacterial conversion of nitrates into harmless nitrogen gas.
56.	Graphic: Land treatment, showing land application, evaporation, runoff and percolation	When used as an advanced process, land treatment, as well as serving as a secondary treatment process, can accomplish removals of organic matters and nutrients which make it the equivalent of other advanced treatment processes. By applying wastewater to the land, the phosphorus and nitrogen are utilized by growing plants or removed by reactions in the soil. Organic materials are consumed by microorganisms present in the soil and suspended particles are removed by filtration through the soil. Finally the water evaporates, runs off, or passes down into the soil.
57.	Picture: Carbon feeder	Activated carbon can be used to remove organic matter from wastewater either as a substitute for biological treatment or as a polishing step to remove additional organic matter following secondary biological treatment. Because of the large surface area of the carbon, organic substances tend to stick to it. This process uses either powdered or granular carbon which is much like charcoal in a cigarette filter.

58.	Graphic:	PAC with wastewater	When powdered carbon is used, it is mixed with the wastewater and then removed by settling or filtration or both.
59.	Picture:	Granular carbon beds	However when granular carbon is used, it is placed in columns or beds and the wastewater is allowed to flow through it.
60.	Picture:	Regeneration furnace for GAC	Granular carbon has the advantage in that it can be regenerated and reused. This regeneration is done in a furnace using heat and steam.
			MUSICAL BRIDGE
61.	Picture:	Holding tank with overlay saying SOLIDS HANDLING ALTERNATIVES	The essence of wastewater treatment is the separation of solids from liquid. Solids from all these primary, secondary and advanced waste treatment processes must be collected, treated and disposed. The cost of this solids handling is often equal to the cost of all the other treatment processes.
62.	Diagram:	Thickener, centrifuge and incinerator	At the Swatara plant, the sludge was allowed to thicken by settling in a tank, and was then aerated. The water was removed by a centrifuge, and finally it was burned to an ash.
63.	Graphic:	Aerobic digestion	What if we let the microorganisms eat the sludge? This process is called sludge digestion and can either be an aerobic or anaerobic process. In aerobic digestion the sludge is put in a tank and air is pumped into the sludge to provide oxygen. The organisms digest the sludge until it is stabilized (which means it has an earthy odor and much less organic content).
64.	Graphic:	Anaerobic digestion	Anearobic digestion does the same job as aerobic digestion since it also stabilizes the sludge and converts it into an inoffensive solid with an earthy odor. A beneficial byproduct of anaerobic digestion is the methane gas which the process produces and which can be used as an energy source. Its first use as an energy source is to provide the heat that makes the process work most efficiently.

65. **Picture: Wet air oxidation**

An alternative to biological sludge digestion is wet air oxidation. In this process the sludge is mixed with air and steam at a high temperature and pressure. After this severe treatment the solids, which have been stabilized in the process, are removed from the liquid by settling and safely disposed.

66. **Graphic: Flotation thickening**

One alternative to the already discussed processes of gravity thickening and centrifugation for sludge concentration is flotation thickening. In flotation thickening, air is mixed in with the sludge in a pipe and the mixture pumped into a tank. The air bubbles cling to the sludge particles causing them to float to the surface where skimmers remove the thickened sludge.

67. **Picture: Drying beds**

Another alternative for concentration is the sludge drying bed, where the sludge is spread out on large sand beds and allowed to dry in the open air.

68. **Graphic: Belt filter press**

Still another method is a filter press. Here the sludge is compressed between two belts and the water is literally wrung out of the sludge.

69. **Picture: Sludge vacuum filter**

Instead of squeezing the water out of the sludge, it can be drawn out on a vacuum filter. The water is pulled through a fine cloth or wire coil filter by a vacuum. The cloth or coils rotate on a drum so that the sludge which has stuck to the filter can be removed.

70. **Picture: Ash Burial**

All alternatives for concentrating sludges require conditioning of the sludge prior to using the process. Without conditioning the sludge does not give up its water easily and thus the concentration processes are not very efficient. This conditioning can be done through the addition of chemicals or heat to the sludge.

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71.	Picture: Ash burial	The remaining solids after the sludge is stabilized must be disposed. At the Swatara plant, the solids were incinerated and the ash was buried.
72.	Picture: Land spreading by spraying liquid sludge	At many other treatment plants the solids, instead of being incinerated, are spread on land where they act as a soil conditioner. Land spreading can be done with either liquid or
73.	Picture: Spreading dewatered sludge	concentrated sludge and is very often considerably cheaper than incineration. Alternatively the sludge might be buried in a land fill.
		MUSICAL BRIDGE
74.	Word Graphic: Alternative Choices	In summary, you have seen many methods for primary, secondary and advanced wastewater treatment and sludge disposal. There are at least one hundred different treatment processes that might be considered, including innovative and alternative processes.
75.	Picture: Advisory group	In the selection of the proper sequence of processes to be used, careful consideration of the area's needs and resources must be taken into account by the community, its consultant and the advisory group.
76.	Graphic: Things to consider	This consideration will include such items as the cost-effectiveness, or that sequence of processes that will do the job with the least amount of money; environmental effects; resource consumption including energy use; wastewater characteristics; effluent requirements as determined by your regulatory agency
77.	Graphic: Things to consider, continued	sludge handling and disposal; reliability and flexibility; implementation capability and public acceptance.
78.	Photo: Wastewater treatment plant	With such consideration a wastewater treatment plant can be constructed that will do the job it was designed to do, is cost effective, and is accepted by the community.
79.	Credit slide	MUSIC

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Working for Clean Water is a program designed to help advisory groups improve decision making in water quality planning. It aims at helping people focus on essential issues and questions, by providing trained instructors and materials suitable for persons with non-technical backgrounds. These materials include a citizen handbook on important principles and considerations about topics in water quality planning, an audiovisual presentation, and instructor guide for elaborating points, providing additional information, and engaging in problem-solving exercises.

This program consists of 18 informational units on various aspects of water quality planning:

- Role of Advisory Groups
- Public Participation
- Nonpoint Source Pollution: Agriculture, Forestry, and Mining
- Urban Stormwater Runoff
- Groundwater Contamination
- Facility Planning in the Construction Grants Program
- Municipal Wastewater Processes: Overview
- Municipal Wastewater Processes: Details
- Small Systems
- Innovative and Alternative Technologies
- Industrial Pretreatment
- Land Treatment
- Water Conservation and Reuse
- Multiple Use
- Environmental Assessment
- Cost-Effectiveness Analysis
- Wastewater Facilities Operation and Maintenance
- Financial Management

The units are not designed to make technical experts out of citizens and local officials. Each unit contains essential facts, key questions, advice on how to deal with the issues, and clearly-written technical backgrounds. In short, each unit provides the information that citizen advisors need to better fulfill their role.

This program is available through public participation coordinators at the regional offices of the United States Environmental Protection Agency.